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Energetic transition in Iran

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Abstract

In this paper, we study the effects of renewable energy consumption on economic growth in Iran in the period 1983 to 2013, through Autoregressive Distributed Lag (ARDL) method. Results show that an increase in renewable energy consumption increases economic growth. In other words, there is a positive and statistically significant relationship between renewable energy consumption and economic growth. The results show that in the long-run 1% increase in consumption of renewable energy leads to 4.06% increase in economic growth; they also show that in a short-run, 1% increase in it also can lead to 7.5% increase in economic growth.

Keywords: Renewable energy consumption, economic growth, autoregressive distributed lag method

JEL Classification: Q22, O44, F21

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Introduction

After Cop 21 agreement on December, 12th 2015, UN Secretary General Ban Ki-Moon said: “We have entered a new era of global cooperation on one of the most complex issues ever to confront humanity. For the first time, every country in the world has pledged to curb emissions, strengthen resilience and join in common cause to take common climate action. This is a resounding success for multilateralism.” This builds on the momentum of the unprecedented effort which has so far seen 188 countries contribute climate action plans to the new agreement, which will dramatically slow the pace of global greenhouse gas emissions.

In this background of post-COP 21, low oil prices and development of renewable energies, studying the energy transition in an oil-exporting country such as Iran makes sense. There is strong political will to seize the moment, especially with the Paris Agreement on Climate Change now in force.

Energy transition means a long-term structural change in energy systems. Renewable energy serves as an alternative to fossil fuels (oil, coal, natural gas) and nuclear fuel (uranium) and encompasses wind, biomass (such as landfill gas and sewage gas), hydropower, solar power (thermal and photovoltaic), geothermal, and ocean power. 'Energy transition' also designates a significant change in energy policy: a reorientation of policy from demand to supply and a shift from centralized to distributed generation, which should replace overproduction and avoidable energy consumption with energy-saving measures and increased efficiency.

The Iranian economy is heavily dependent on the oil and gas sectors. The vagaries of oil markets and Iran's reliance on a single resource for most of its income have created disincentives to develop a more diversified and globally integrated economy. Iran's oil and gas sectors have faced key structural problems. On the demand side, subsidized prices and a population that has doubled since the 1979 revolution have created excessive demand. On the supply side, an aging oil resource base has been stymied by financial constraints, technical shortages, sanctions, and using gas to stimulate oil production. Iran is facing pressures to curb its greenhouse gas emissions and needs to explore alternative energy sources, including nuclear options. Iran government stopped to subsidize the fossil combustibles and they are preparing their economy to the energy transition.

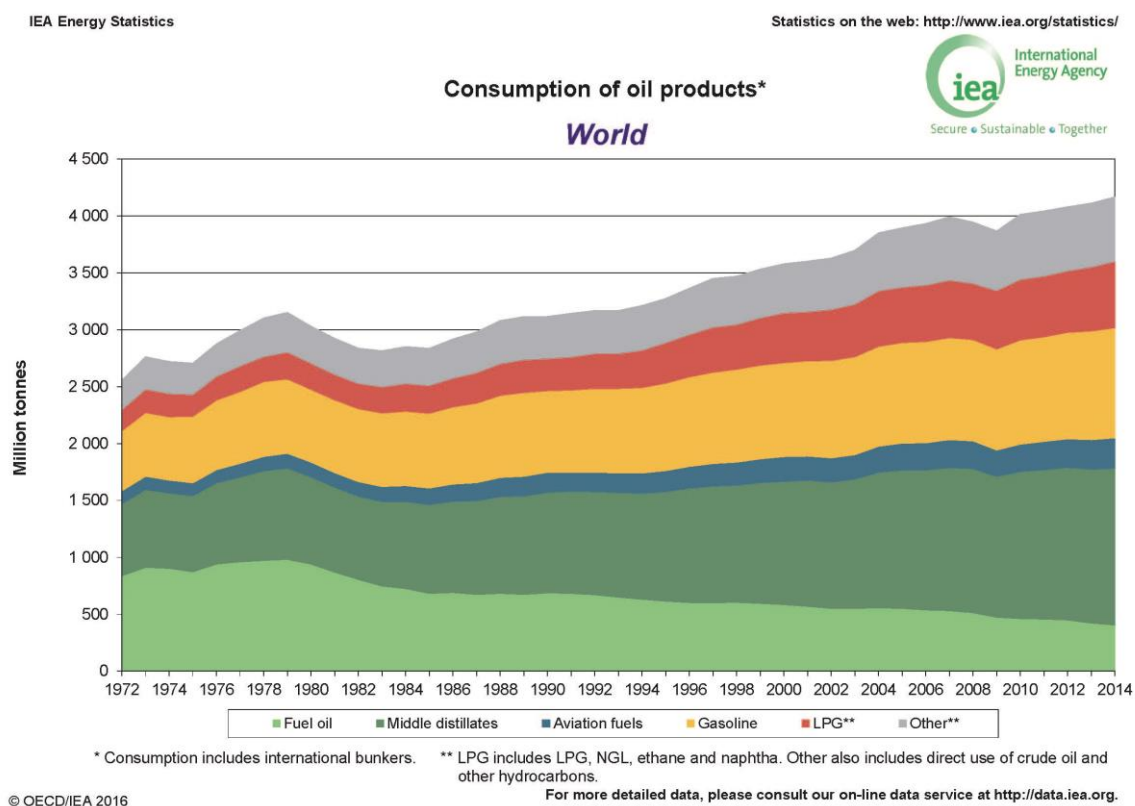
Using econometrics, we intend to assess the economic impacts of the energetic transition on the GDP. For our analysis, we will use data from local sources such as Iran Renewable Energy Organization (SUNA) under the Iranian Ministry of Energy and international sources like IAE, 2015: “World Energy Outlook 2015”. SUNA has begun to work on the renewable energy since 1996, so we completed our dataset with figures from the Central Bank of Iran..

Several questions are related to our study: What will be the impact of energy transition on the macroeconomic variables and policy? What would be the new objectives of the Iranian government? How the governance will consider the renewable energies? What will be the costs of adaptation at different levels: social, environmental and economic? Is Iran capable of founding a way towards a sustainable development with less emphasis on oil revenue?

I- The evolution of the sources of energy in the world

Since the industrial revolution, the economies are highly dependent on low cost and easy access energy. More than 80% of the world energy is fossil, but because of the CO₂ emissions and their consequences on climate change, they should be mitigated and the population should adapt. The energy transition is crucial for fighting climate change and achieving the sustainable development. The term “energy transition” means a significant change in energy policy and solving the energy problem is regarded as the most important challenge facing humankind in the 21st century because oil products are main sources of energy (figure 1).

Figure 1:



Energy is essential for economic growth and preservation of the environment. To end extreme poverty and promote shared prosperity, access to affordable, reliable and sustainable energy is vital. Modernizing energy services means improving the quality of life of millions of people around the world and bolstering progress in all areas of development. Globally, almost 1.1 billion people (about the equivalent of the Indian population) still do not have electricity. Most of these populations are concentrated in Africa and Asia. They are also \$ 2.9 billion dependent on wood or other biomass fuels for cooking and heating, resulting in indoor and outdoor air pollution that causes 4.3 million deaths each year. The World Bank's commitment to the energy sector aims to support developing countries in securing the reliable, sustainable and affordable

energy supply they need to end extreme poverty and promote shared prosperity thanks to an environmentally, financially, fiscally and socially sustainable energy sector.

The United Nations' Sustainable Energy for All (SE4All) initiative, jointly led by the World Bank, aims to achieve three objectives by 2030: ensure universal access to electricity and clean fuels for cooking food, multiply by two the share of renewable energy in the global energy mix and double the improvement of energy efficiency. These three aspects are the basis of the seventh of the 17 Sustainable Development Goals (SDGs), which set targets to be achieved by 2030 in order to incorporate the social, economic and environmental dimensions of sustainable development. Eighty-five countries subscribe to the SE4All initiative, whose implementation is supported by many public, private and non-governmental actors. The World Bank is working to achieve this by focusing on a comprehensive, long-term approach, with robust financial, operational and institutional arrangements, by stimulating private sector participation and investment, by supporting the development of energy projects using an inclusive and multi-stakeholder approach, and by assessing the different national contexts in order to adapt. Another project, "Readiness for Investment in Sustainable Energy" (RISE), provides indicators for comparing national investment climates in the three areas covered by the SE4All initiative.

For the first time, renewable sources of energy have overtaken coal in terms of cumulative installed power capacity in the world (figure 2). In 2015, an all-time record 153 gigawatts (GW) of capacity was added through renewables, with photovoltaic solar - which includes mini-grids and rooftop solar systems - accounting for nearly a third (49 GW) of the addition, according to the International Energy Agency (figure 3). About half a million solar panels were installed every day around the world last year. Solar power is a game changer for developing countries that are swiftly embracing this renewable source of energy to close their electricity access gaps and meet climate change mitigation goals. In June 2016, the World Bank Group signed an agreement with the International Solar Alliance, consisting of 121 countries led by India to collaborate on increasing solar energy use around the world and helping the alliance mobilize \$1 trillion in solar investments by 2030. Even the IMF advises fiscal reforms and carbon pricing to promote greener growth.

Figure 2:

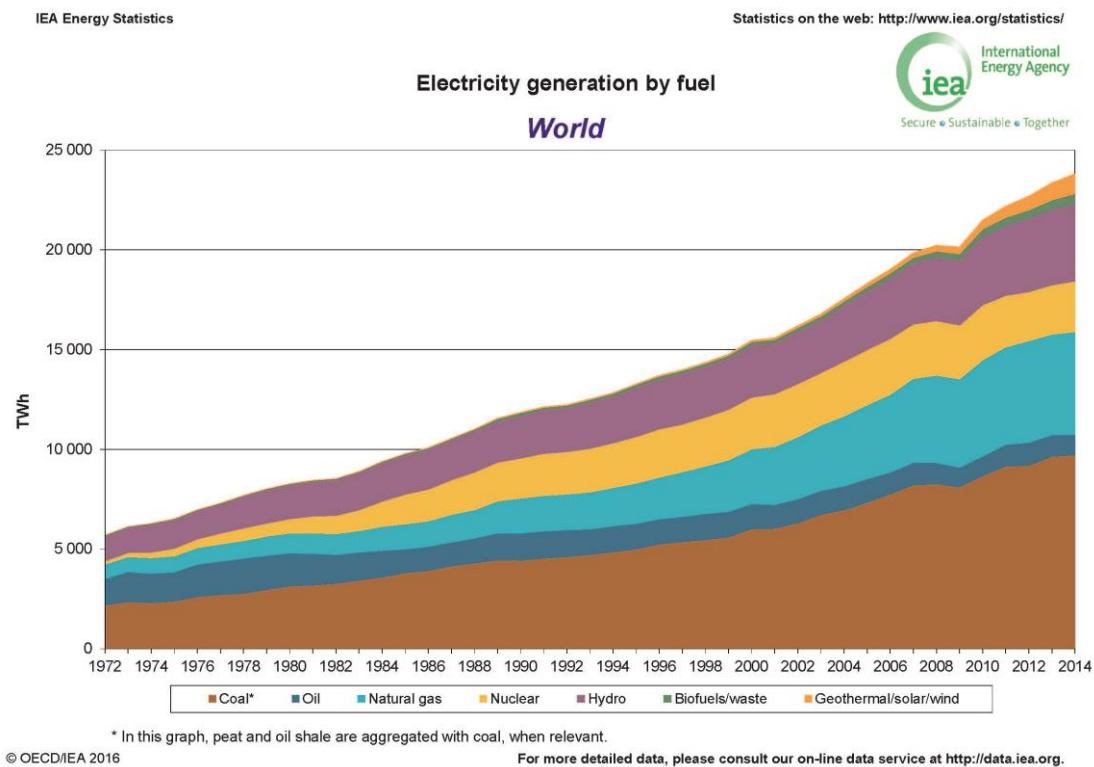
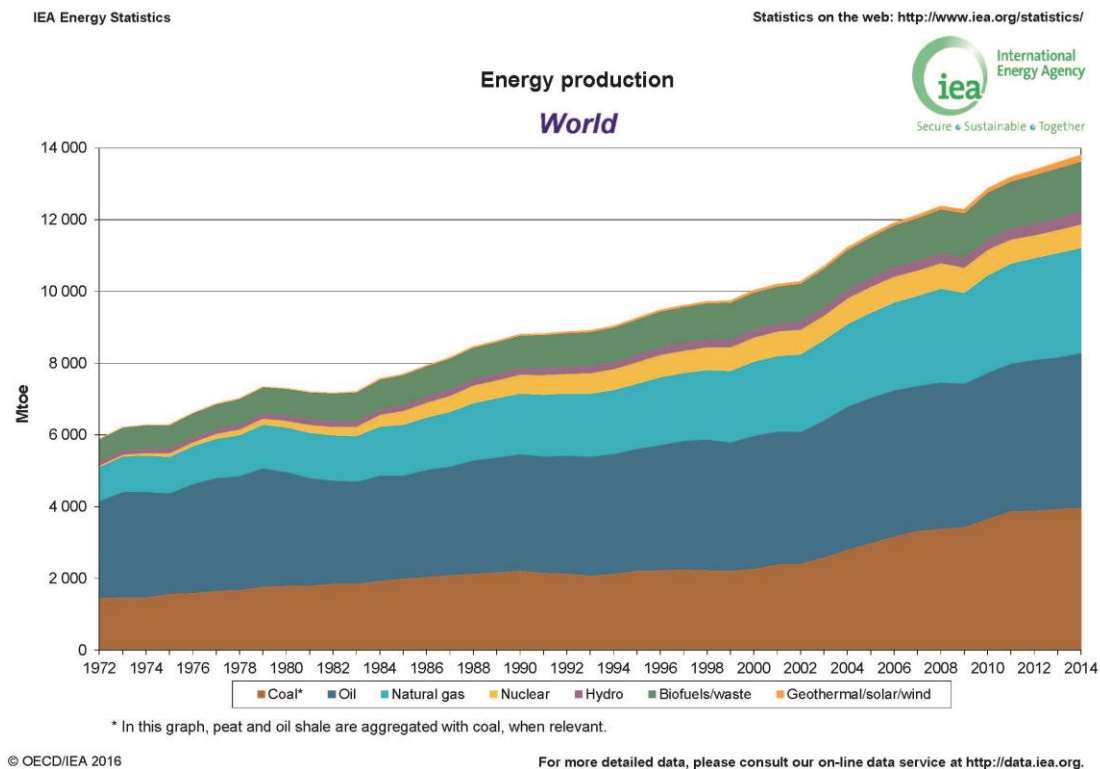


Figure 3:

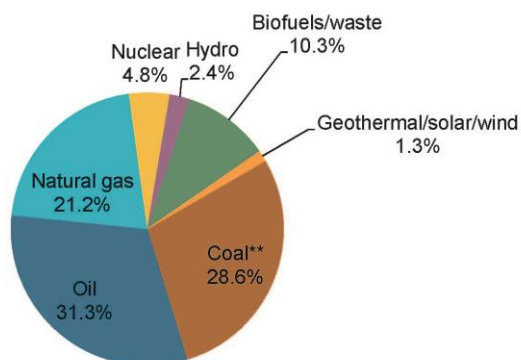


The global economy grew by around 3% in 2014, but energy-related CO₂ emissions stayed flat. Renewables accounted for about half of all new power generation capacity in 2014. Around 11% of global energy-related CO₂ emissions come in areas that operate a carbon market (like the European Union's Emissions Trading Scheme) and 13% in markets with fossil-fuel consumption subsidies (India, Indonesia, Malaysia and Thailand diminish their fossil-fuel subsidies thanks to lower oil prices). The link between economic output and energy-related GHG is weakening. China is supposed to decouple its economic expansion from emissions growth by around 2020 thanks to improvements of energy efficiency of industrial motors and the building sector. The pace of this decoupling is 30% faster in the European Union (improved energy efficiency) and in the United States (development of renewable energy) (figure 4 and 5).

Figure 4:

Share of total primary energy supply* in 2014

World



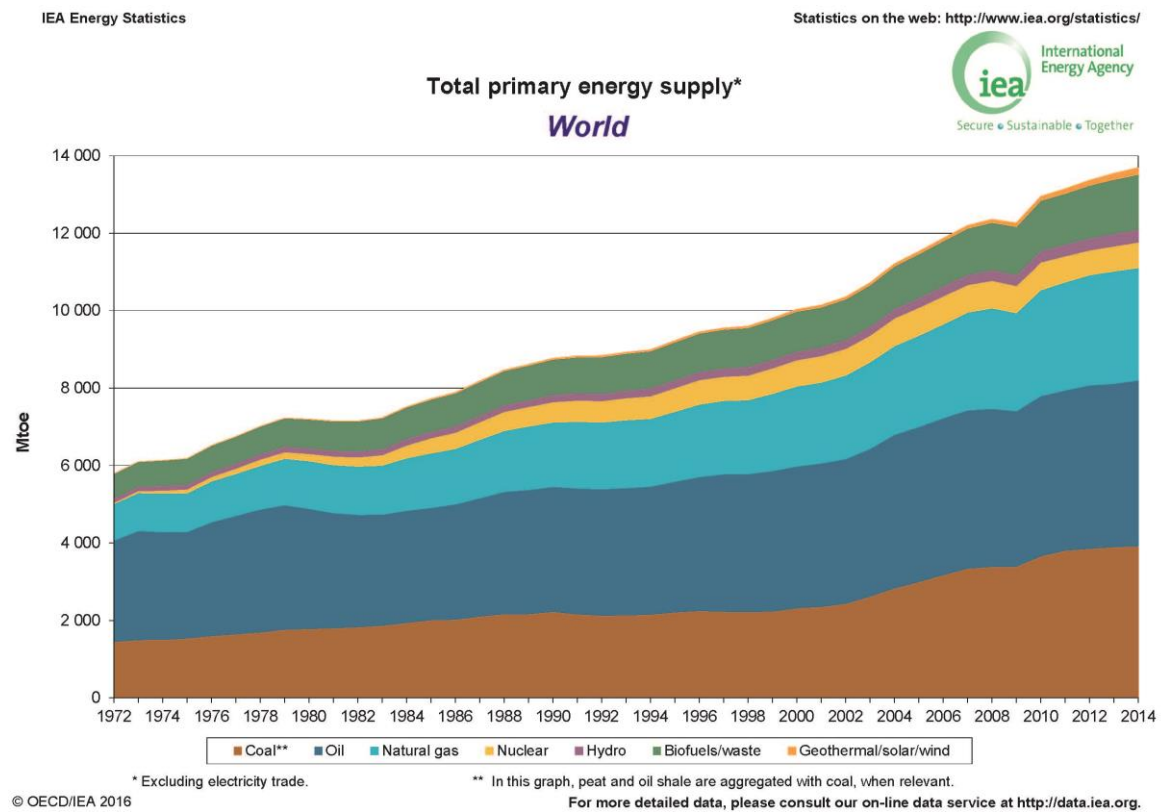
13 699 Mtoe

* Share of TPES excludes electricity trade.

** In this graph, peat and oil shale are aggregated with coal, when relevant.

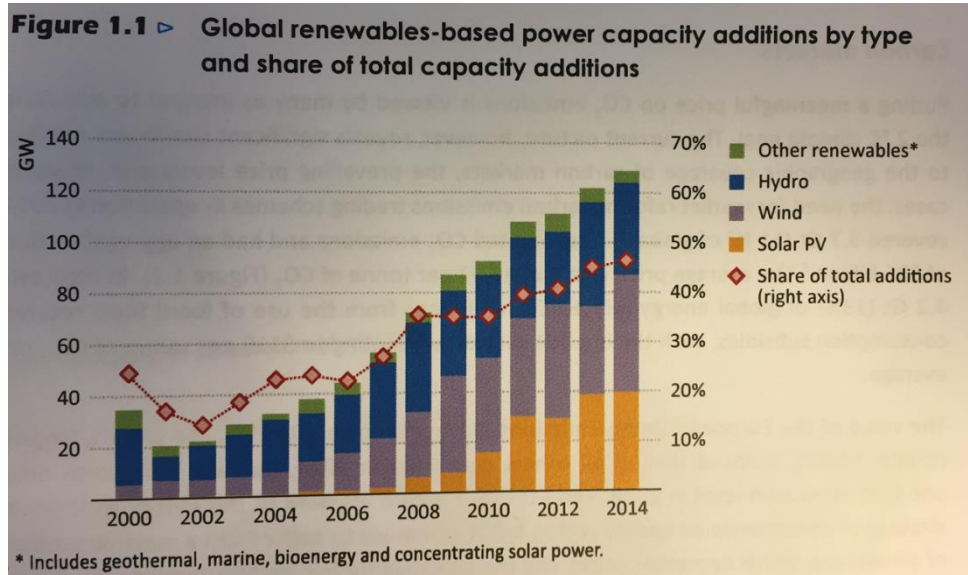
Note: For presentational purposes, shares of under 0.1% are not included and consequently the total may not add up to 100%.

Figure 5:



An important change in the energy sector from 2014 to 2015 has been the rapid drop in world oil prices and, to a lesser extent, natural gas and coal prices. After a prolonged period of high and relatively stable prices, oil dropped from over \$100 per barrel in mid-2014 to below \$50 in early-2015. Natural gas prices also declined, but the pace and extent depended on prevailing gas pricing mechanisms and other regional factors. At the global level, lower fossil-fuel prices are likely to act as a form of economic stimulus, which the International Monetary Fund (IMF) quantifies at between 0.3% and 0.7% of additional growth in global gross domestic product (GDP) in 2015 (IMF, 2015). Yet, so far regional impacts have varied hugely between net importers and exporters, large and small consumers and countries with fossil-fuel subsidy schemes and those without. Oil and gas exporters have seen their expectations of economic growth trimmed and many have revised government budgets as a result. For oil and gas companies, the drop in prices has prompted a significant reduction in planned upstream investments – estimated to be around 20% lower in 2015. Renewable technologies are becoming increasingly cost competitive in a number of countries and circumstances, but public support schemes are still required to support deployment in many others. Renewables-based power generation capacity is estimated to have increased by 128 GW in 2014, of which 37% is wind power, almost one-third solar power and more than a quarter from hydropower (Figure

1.1). This amounted to more than 45% of world power generation capacity additions in 2014, consistent with the general upward trend in recent years. The growth in wind capacity continued to be led by onshore installations (although offshore has also grown rapidly). Nuclear power is the second-largest source of low-carbon electricity generation worldwide, after hydropower. Nearly all new nuclear construction in recent years has taken place in price-regulated markets or in markets where government-owned entities build, own and operate the plants.



II- The sources of energy in Iran

Having access to a variety of renewable energy for developing countries plays an essential role in their development processes. In some models, such as the biophysical growth model proposed by Ayres and Nair (1984), energy has been considered as the most important factor of economic growth. Oil has a crucial role for the Iranian economy (figure 6). For Iran, limited fossil resources, high increase in energy consumption per capita, reduction in oil exports and consequently an important reduction in oil revenues, in combination with absence of a long-run planning, has a very important impact on the development process of the country. In this case, using the renewable resources is inevitable (figure 7).

Figure 6:

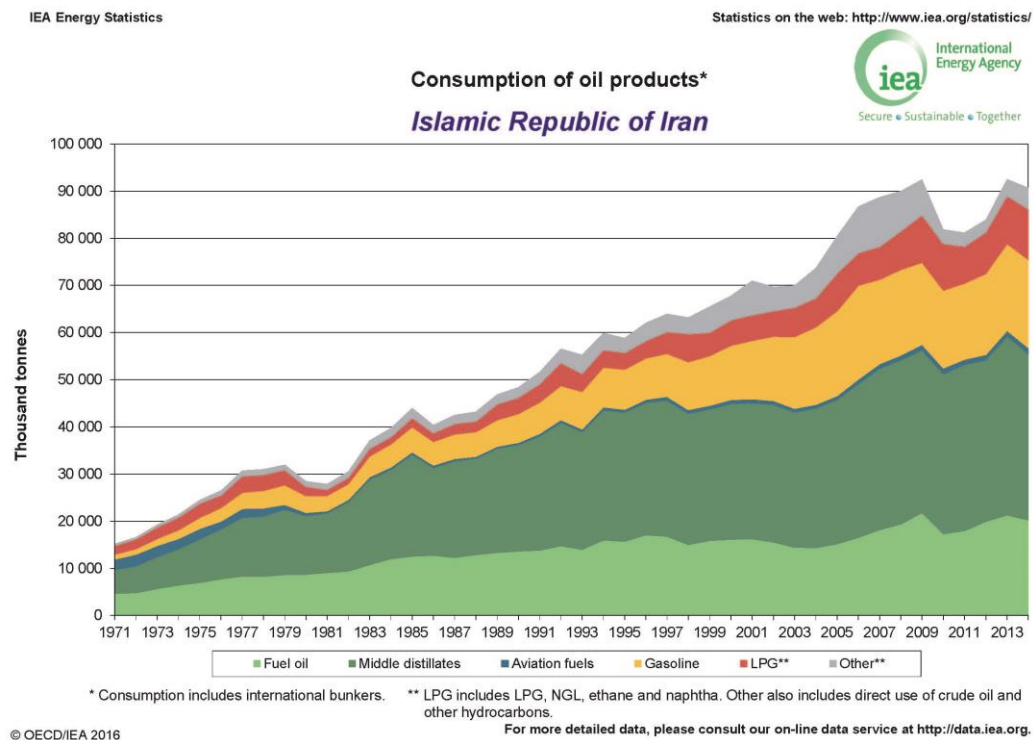
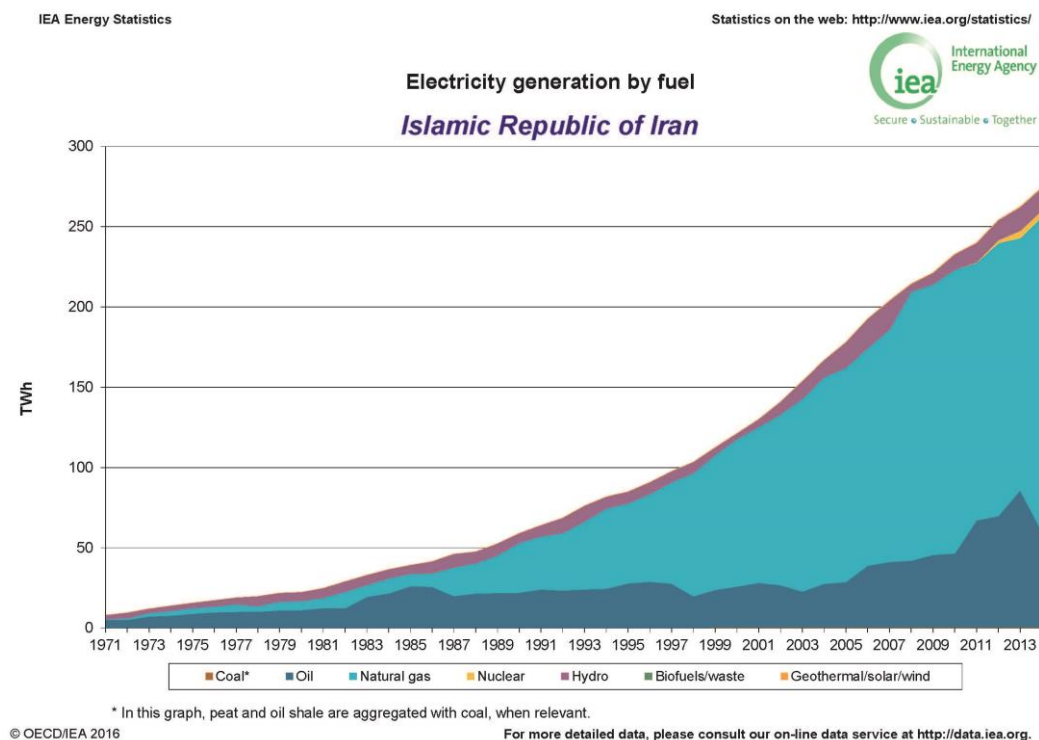


Figure 7:



Unlike fossil fuels, renewable energies are able to return to environment. Most important resources of renewable energies are solar, wind, Hydroelectric and biomass (figure 8 and 9). Keep healthy environment and reduce air pollution are the essential reasons to use the renewable energies. Political and economic crises, overcrowding population and environmental concerns are the universal problems for which scientists should find the sustainable solutions for the world's energy problems. Reduction of fossil fuels resources is not only a threat for oil exporting countries, but also a major concern for other countries as well.

Figure 8:

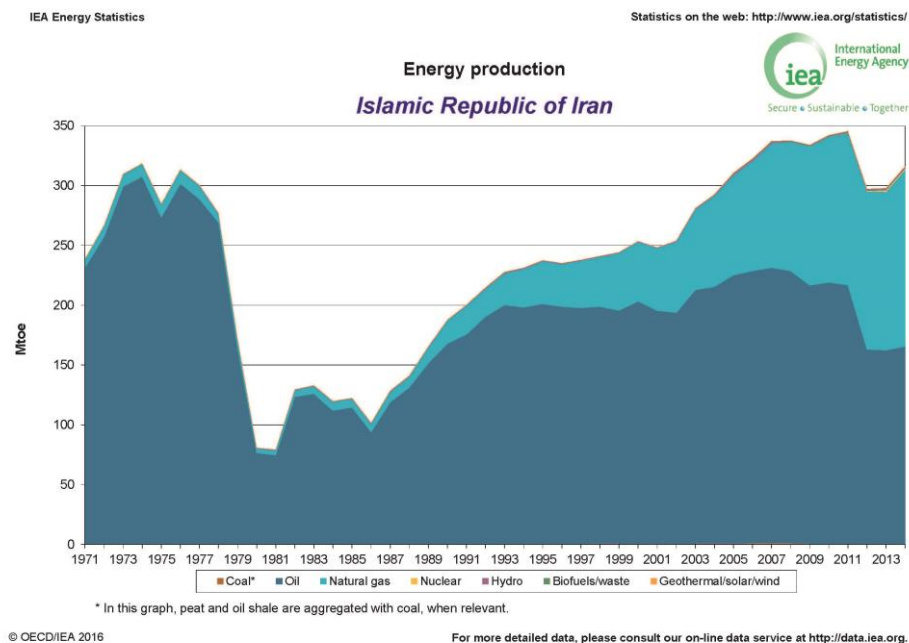


Figure 9:

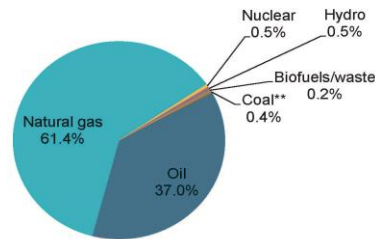
IEA Energy Statistics

Statistics on the web: <http://www.iea.org/statistics/>



Share of total primary energy supply* in 2014

Islamic Republic of Iran



237 Mtoe

* Share of TPES excludes electricity trade.

** In this graph, peat and oil shale are aggregated with coal, when relevant.

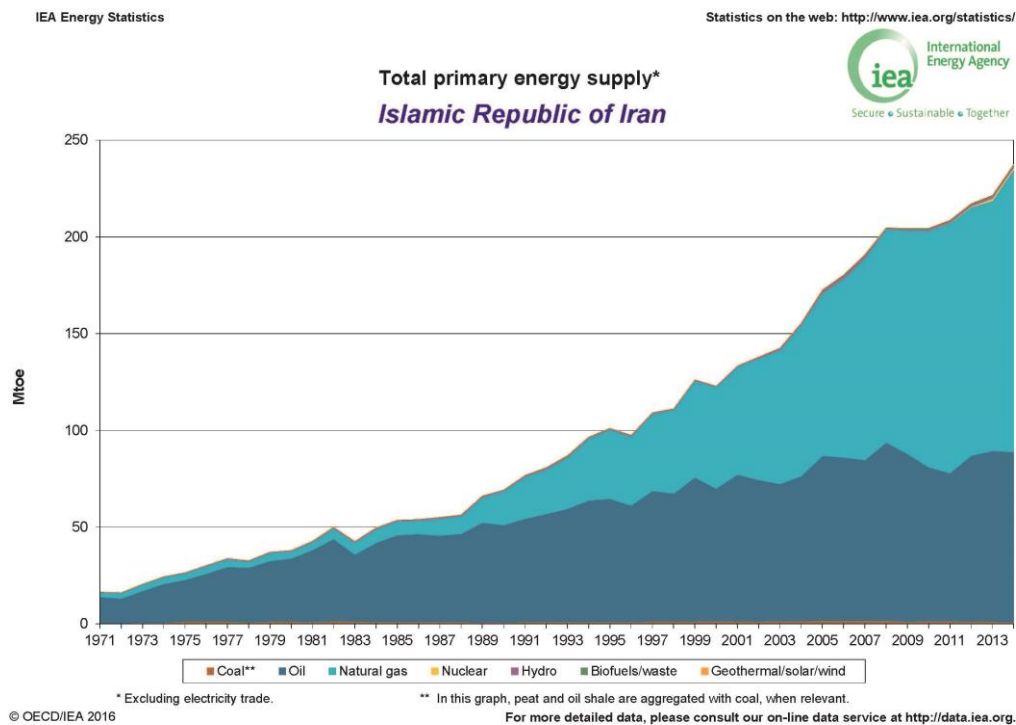
Note: For presentational purposes, shares of under 0.1% are not included and consequently the total may not add up to 100%.

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Renewable energy development has several advantages in Iran, including enhancing the security of energy supply, reducing global warming, stimulating economic growth, creating jobs, increasing income per capita, protecting environment, etc. But it is still very limited (figure 10).

Figure 10:



III- The relationship between renewable energy consumption and economic growth in Iran

Thanks to our model, we try to find the effects of renewable energy consumption on economic growth for Iran. In the used model, log of GDP is the dependent variable whose changes indicate economic growth. Independent variables in this study are: occupation, capital formation and renewable energy consumption. The aim of the work is to examine the role of renewable energy on economic growth.

1. Theoretical foundations and literature review

Many studies have investigated the relationship between energy resources and economic growth. Some of them like Lee & Chang (2007) and Wolde-Rufael (2009) are focused on a specific country, however some others like Akinlo (2008) and Fuinhas and Marques (2012) have chosen a group of countries for their researches.

Apergis and Payne (2010) have used a Vector Error Correction Model (VECM) to study the relationship between renewable energy consumption and economic growth on 20 OECD countries. Results show both short-term and long-term bilateral causal relationships between renewable energy consumption and economic growth in these countries.

Menegaki (2011) has used an Error Correction Model (ECM) to show the causal relationship between renewable energy consumption and economic growth for 27 European countries. According to the paper results, there are no evidences which confirm Granger causality from renewable energy consumption to economic growth in short term as well as in long term.

Oh and Lee (2004), in a paper entitled “Energy consumption and economic growth in Korea”, try to show the relationship between energy consumption and economic growth. The results show a causal bilateral relationship between energy consumption and economic growth in long term. In short term the causality goes from energy to GDP.

Fang (2011), in his paper named “Economic welfare impacts from renewable energy consumption: The China experience” shows a high correlation between economic welfare and renewable energy consumption.

Capital and labor are the most important factors of production. In recent theories, energy has been considered as a very important factor of production as well. In accordance to Biophysical economic growth theory proposed by Ayres and Nair (1984), energy is the most important factor of economic growth, and labor and capital are considered as the intermediate factors for growth so that they use energy themselves.

Renewable energies could affect the economic growth in two different ways. On one hand, an increasing use of this type of energy creates new jobs and increases the production and sales of the technology related to this type of energy. On the other hand, the increase in renewable energy production leads to a decrease in fossil fuel-based power productions, which causes

unemployment and negative economic growth. Hence, its impact is ambiguous on economic growth.

According to the above model, if production is a function of physical capital, labor and energy, therefore, the general function of production is:

$$Y_t = F(K_t, L_t, EC_t) = A_t K_t^\alpha L_t^\beta EC_t^\gamma$$

Where Y_t indicates total production. A_t , K_t , And L_t are representing technology, capital stock, and labor, respectively, and EC_t shows energy consumption.

2. The Model

The model and the variables are discussed in this section. Two hypotheses are considered in the study:

- a. An increase in the use of renewable energy in short-term, has have no effect on economic growth in Iran.
- b. An increase in the use of renewable energy in long-term, has have no effect on economic growth in Iran.

In the study, we use a Cobb–Douglas production function. The general form of the production function is:

$$Q = AL^\alpha K^\beta$$

By adding the consumption of renewable energy, the logarithmic shape of Cobb–Douglas function can be shown as:

$$\log Y_t = A + \alpha \log L_t + \beta \log K_t + \gamma \log EC_t + \xi_t$$

Where:

$\log Y_t$ is the logarithm of gross domestic product (GDP) (in accordance which we can calculate economic growth), $\log L_t$ is the logarithm of Labor input, $\log K_t$ is the logarithm of capital stock (the amount of money used to take over the machinery, equipment and buildings), $\log EC_t$ is the logarithm of renewable energy consumption, and α , β , γ represents production elasticity of labor, capital and renewable energy, respectively.

This model has been estimated for Iran for the period of 1983 to 2013. The data are taken from the Central Bank of Iran and International Energy Agency (IEA).

3. Model estimation method

In most time series models, economic variables tend to move in a same direction because of a common trend in them. Estimating of a regression model using non-stationary time series variables may lead to a spurious regression (Noferesti, 1999).

One way to avoid a spurious regression is to use the difference of variables (differential equations). But these equations do not provide any information on long-term relationship between the variables. In such circumstances, we can use the cointegration Methods and estimate the model without worrying about spurious regression problem. Autoregressive Distributed Lag (ARDL) is a cointegration method can be used in such models.

If the data sample is large and economic variables have been cointegrated, OLS estimators would be consistent. But, if the sample size is small, or variables are not cointegrated, using OLS method for estimating a long-run relationship, the estimators would be biased due to ignoring dynamic reactions. Therefore, it seems to be reasonable to use dynamic methods for estimating the exact coefficients. In this method, to eliminate the bias due to small sample size, the lags of depended variable are considered.

The mechanism of the ARDL, developed by Pesaran & Shin (1997) has several advantages. In fact the most important advantage is that it can estimate the model, regardless of whether that variable is I(0) or I(1). Another advantage of this model is that the dynamic Error Correction Model (ECM) can be calculated from an ARDL model by a simple linear transformation.

4. The analysis of results of studies

In the estimation of a time-series regression model, it is important to check the stationary of the variables, which can be done through Augmented Dickey–Fuller test (ADF) test. According to the results of ADF statistics, and the comparison to critical values in Table 1, economic growth (G), is stationary in level. The log of labor (LL), the log of capital stock (LK) and the log of renewable energy consumption (LEC) are also became stationary through first order differencing.

Table 1. Stationary test of the model variables using the ADF test

Variable	ADF statistic	Critical value	Optimal lag	Convergence degree
G (Economic Growth)	-3.61	-2.97	1	I(0)
LL (Log of Labor)	-4.60	-2.97	1	I(1)
LK (Log of Capital)	-5.47	-2.97	0	I(1)
LEC(Eenewable Energy Consumption)	-2.55	-2.97	1	I(1)

Source: research results.

ARDL model analysis is based on three dynamic, long-term and error correction equations. The results of estimating the dynamic equation are summarized in table 2.

Table 2. The results of the dynamic equation estimation

Variable	Coefficient	t-statistic
Intercept	-43.99	-1.77
LL (log of Labor)	2.59	1.85
LK (log of capital stock)	13.6	2.51
LEC (log of renewable energy consumption)	7.58	2.59
R ² = 0.4		
DW = 2.6		

Source: research results.

According to the results showed on table 2, renewable energy consumption has a positive and significant effect by a coefficient equal to 7.58 on economic growth in short-term. As expected, the impact of capital stock on economic growth is positive by a coefficient equal to 13.6. The coefficient of active labor (LL) is also positive and equals to 2.59, and has a significant effect on the dependent variable, in a 90% confidence interval.

Table 3 shows the results of tests on classical assumptions for ensuring the efficiency of estimations. Results show a normal distribution for error term. Also, there is no autocorrelation in error term and there is no heteroscedasticity. Thus, according to results, classical assumptions are satisfied.

Table 3. Results of diagnostic tests

Test	LM test	F-test	Results
Autocorrelation hypothesis	0.07677 (0.782)	0.0577 (0.812)	Rejected
significant form	0.7296E (0.978)	0.542E (0.982)	Accepted
Normal distribution	0.344 (0.842)	-	Accepted
Variance heteroskedasticity	0.52081 (0.470)	0.4927 (0.489)	Rejected

Source: research results.

After estimating the dynamic equation, we are going to test the presence or absence of cointegration hypothesis between variables of the model. For convergence test, we use Banerjee, Dolado & Mestre (1992) test. If the sum of estimated coefficients of lags of the dependent variable is less than 1 ($\sum_{i=1}^p \alpha_i < 1$), then the dynamic model tends toward long-term equilibrium model. Null hypothesis is based on absence of cointegration, and the alternative hypothesis is based on integration between the variables. The t-statistics is calculated by:

$$t = \frac{\sum_{i=1}^p \hat{\alpha}_i - 1}{\sum_{i=1}^p 5\hat{\alpha}_i}$$

Since the estimated coefficients of the lags of dependent variable are -0.37 and -0.48, and their standard deviations are 0.21 and 0.22, then t-statistic is equal to -4.20. Since its absolute value is bigger than critical value (-3.91), which has been proposed by Banerjee, Dolado & Mestre (1992), hence the null hypothesis H_0 reject, the alternative is accepted. In other words, there is a long-term equilibrium relationship between the variables in the model.

Table 4. The results of the estimation of the long-term model

Variables	Coefficient	t Indicator
Intercept	-23.59	-1.88
LL (log of Labor)	1.39	1.74
LK (log of capital)	7.30	3.20
LEC (log of renewable energy consumption)	-4.06	3.03

Source: research results.

Based on the results summarized in table 4, the research model can be specified as follows:

$$\text{LGDP} = -23.59 + 1.39 \text{ LL} + 7.3 \text{ LK} + 4.06 \text{ LEC} + e$$

in which e is the error term. According to table 4, all independent variables (Labor, Capital and renewable energy consumption) have positive and significant impacts on the dependent variable.

Cointegration relationships between a set of economic variables, provide a statistical base for using ECM. ECM connect short-term fluctuations to the long-term equilibrium values; it is the most important reason to use this method. According to table 5 the coefficient of the Error Correction Model or ECM(-1) is equal to -1.86. This coefficient shows that in each period, 1.86 of short-term disequilibrium would be adjusted to reach a long-term equilibrium.

Table 5. Results estimated from Error Correction Model

Variable	Coefficient	t-statistic
ECM (-1)	-1.86	5.31

Source: research results.

Conclusion

The results of our study in Iran show that in short-term, as well as long-term, renewable energy consumption lead to increase GDP and economic growth. Indeed, these energies help macroeconomic productivity by providing employment and other economic benefits. Renewable energy consumption could also have indirect positive impacts on GDP by increase in capital formation. Hence, it is recommended increasing the use of this kind of energy and to replacing fossil fuels. This model can be replicated in other countries.

Renewable energy sources are more cost-competitive than ever, and the Middle East, driven by the GCC, has tripled its investments in renewables from 2015. There are key indicators showing a major shift in the regional dynamic for renewables for the next decade and beyond. Kuwait and Bahrain are targeting five percent of installed capacity from renewables by 2020. The United Arab Emirates (UAE) plans to derive 21 percent of its power from clean sources by 2021. The solar power plant Shams 1 set in March 17, 2013 at Madinat Zayed in Abu Dhabi is the largest renewable energy project in the Middle East. Shams 1 covers 2.5 square kilometres in Madinat Zayed in the Western Region, and will generate 100 megawatts of clean and sustainable energy helping Abu Dhabi's goal of obtaining 7 percent of its energy from renewable sources by 2020. Jordan will connect 1,800 MW of renewable power to its national grid by the end of 2018 and Egypt plans to raise its share of renewable energy to 20 percent by 2022. In addition, Morocco is expected to have 42 percent of its installed energy capacity from renewable sources by 2020.

There is a paradigm shift in the pace of clean energy deployment in the GCC region. As the Paris Agreement includes a special support to developing countries for adaptation actions, MENA countries are motivated to receive the funds to face the new energy challenges. The 2° C goal should be translated into the energy policy and a low carbon economic growth thanks to the development of new technologies like wind and solar energy, but also energy storage, carbon capture and storage. Investments in energy efficiency need the development of new financing instruments to transform the world's energy system.

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